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Strain-induced magnetic anisotropies in epitaxial CrO₂ thin films probed by FMR technique

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Abstract

Epitaxial CrO₂ thin films were grown onto TiO₂ (1 0 0) single-crystalline substrates by chemical vapour deposition (CVD) process with use of the solid precursor CrO₃. The CrO₂ films with thickness of 27 and 65 nm were deposited onto TiO₂ substrates pre-etched in the diluted HF. The magnetic properties of the epitaxial chromium-dioxide films have been probed by the ferromagnetic resonance (FMR) technique. Analysis of the FMR spectra shows that the magnetic behaviour of the CrO₂ films results from a competition between magnetocrystalline and strain anisotropies. The thin films are heavily strained due to lattice mismatch of CrO₂ epitaxial film with the TiO₂ single-crystalline substrate. For the thinnest film (27 nm) the stress anisotropy dominates, and the magnetic easy axis switches from the *c* direction to the *b* direction of the rutile structure. Unusual angular dependence of the resonance signal and multiple FMR modes are observed for the film with the thickness of 65 nm, where a partial strain relaxation results in appearance of two magnetic phases with mutually perpendicular easy axes along the *c* and *b* directions.

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1. Introduction

Further development of electronics towards higher miniaturization, operation speed, energy efficiency, and enhanced functionality has provided the opportunity of *magnetoelectronic* devices that exploit not only the electrical charge but also the spin of the conducting electrons. Recent progress in magnetoelectronics has been breathtaking and has already resulted in some commercial products [1]. The most critical parameter for the performance of magnetoelectronic devices is the spin polarization of the conduction band of a ferromagnetic component. In this respect, the extremely high polarization (almost 100%) of the conduction band of chromium dioxide (CrO₂) [2–6] has attracted much attention to this material.

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For the practical applications of CrO₂ in magnetoelectronic devices, it is very important to understand the magnetic anisotropies of thin films of CrO₂, and explore possible approaches to control these properties and to tailor them appropriately. High-quality single-crystalline CrO₂ films grown on TiO₂ substrates have been synthesized recently by chemical vapour deposition (CVD) [7], and quite a few papers on their electric and magnetic properties have been published [4–13]. We have demonstrated previously [7,14,15] that the effect of strain anisotropies can become dominant in the ultrathin (≤ 60 nm) CrO₂ films deposited on (1 0 0) TiO₂ substrates. Besides, it is possible to grow strain-free films by skipping the cleaning procedure of the substrate in HF acid [7]. Furthermore, it has been shown that the magnetic anisotropies of the CrO₂ films, depending on specific features of the CVD process, show a very slight or even opposite thickness behaviour [12,13]. Apparently, the morphology of a very thin CrO₂ sub-layer